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Video paper in 180s

Is it possible to evaluate the energy contributions of an estuary?

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This study employs emergy analysis to explore the natural physical foundation underpinning the ecological organization of the Araranguá River estuary, located in southern Santa Catarina, Brazil. The Araranguá River is a 30 km-long estuary formed by the confluence of the Itoupava and Mãe Luzia rivers, with an average annual flow of 1.67 billion cubic meters. The estuary spans an area of 4.63 million square meters within a basin covering 3.02 billion square meters, encompassing 14 municipalities. Human activities such as rice cultivation, livestock farming, and coal mining have caused environmental harm, including soil and water loss and ecological degradation.

The primary objective of this research was to evaluate the emergy signature of renewable natural energy sources in the Araranguá River and quantify their contributions to the system. The energy model for the study area was developed using expert insights, bibliographic references, and field studies. This process involved creating an energy diagram, identifying energy sources, and describing energy stores and flows within the system. The total environmental energy sustaining the Araranguá River estuary amounts to 2.07 million em-Reais annually, including its aesthetic value. Emergy analysis proved effective in identifying key energy sources maintaining the estuary's structure, offering valuable insights for decision-making and public policy development, such as resource allocation and conservation strategies.

The assessment of energy and material metabolism is crucial for understanding human appropriation of natural resources and evaluating the ecological state of systems. This study draws on systems theory and ecology, applicable to all natural phenomena. The methodology is grounded in principles such as maximum power, energy hierarchy, and the pulsating paradigm, enabling a more profound understanding of systemic impermanence driven by energy flow dynamics between biotic and abiotic components. Emergy serves as a universal accounting tool, allowing comparisons across seemingly distinct phenomena by expressing them in common terms. Concepts like thermodynamic entropy and ecosystem irreversibility further illuminate the transient nature of environments.

The energy model for the study area was constructed based on a detailed description of the system, incorporating expert input, literature, and field data. A comprehensive energy diagram was then generated, capturing all known components and processes. The model aggregates comparable elements and procedures, facilitating disaggregation as needed to address

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specific inquiries. The energy assessment model utilizes Howard T. Odum's energy systems language, employing specialized symbols to represent system structure and function.

An emergy assessment table was created using the energy model to quantify the various forms of energy and resources utilized or produced within the Araranguá River estuary. The model consists of equations calculating energy flows and transformations. Data includes annual energy flow (J/year), material flow (g/year), and monetary flow (¥/year or R/year). The total resources sustaining the estuary amount to 1.04 million emReais annually, with the Itoupava and Mãe Luzia rivers contributing 947,000 reais and rainfall adding 78,000 reais.

The ecosystem's contribution to the Araranguá River estuary was evaluated from two perspectives: system-level energy or material flow and environmental costs associated with the estuary's existence. Although not directly addressed, economic activities in the region are influenced by these energy sources. The estuary's aesthetic value, appreciated by residents and tourists, was assessed using the total natural environmental emergy flowing into the system.

Understanding the system through energy flow is complex but realistic. The Araranguá River estuary features a sandy barrier, islands, and a rocky outcrop with dunes near the sea. This outcrop directs the estuary northward and contributes to its scenic beauty. However, the absence of interpretive frameworks in science complicates comprehension of what constitutes authenticity in academic or research contexts.

This study highlights the significance of the Mãe Luzia and Itoupava rivers, along with tides and rainfall, as energy sources for the Araranguá River estuary. It underscores the challenge of recognizing these landscape-forming elements in system management. The rivers traverse multiple municipalities before forming the estuary, necessitating regional cooperation for integrated management that benefits all stakeholders.

The sustainability of the Araranguá system depends on maintaining physical processes essential for its health. Emergy analysis provides a holistic view of the system, aiding evaluation and informing sustainable public policies while minimizing negative impacts. Effective communication and education are vital for conveying complex processes to target audiences.

The emergy approach reveals the estuarine ecosystem's importance to the local economy. The Araranguá River estuary's contribution, valued at 1.04 million emReais/year, underscores its ecological and aesthetic potential. These findings should support public policies aimed at preserving the estuary's ecological and economic value, countering development policies driven by real estate speculation

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

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Author contributions

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

Supplementary material 1

The estuary. Energy and economic contributions

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